

Characterization of the Dynamic Viscoelastic Behavior of Semolina Dough Obtained from Mexican Durum Wheat Cultivars

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Abstract

The main product obtained from durum wheat was semolina, and one of the most important quality characteristics is the rheological properties of its dough. The objective of this work was to evaluate the viscoelastic behavior of semolina dough prepared from commercial Mexican durum wheat cultivars. Thirteen and eleven samples of Mexican durum wheat cultivars from the 2001-2002 and 2002-2003 crop years were obtained from the main producer states. Semolina was made with each wheat cultivar and protein, ash, moisture and wet gluten contents were determined. Viscoelastic behavior of semolina dough was also evaluated using the dynamic test in a controlled strain rheometer. The rheological parameters evaluated were: the storage modulus (G'), the loss modulus (G'') and $\tan \delta$. Wheat cultivar affected significantly the semolina dough viscoelastic properties, mainly the $\tan \delta$. Mexican semolina dough had higher elastic characteristic than viscous one, and both parameters were higher than commercial semolina dough.

Keywords

Durum Wheat; Semolina; Dough Viscoelasticity; Pasta

Introduction

Durum (*Triticum durum*) is the preferred wheat for pasta production due to its unique color, flavor and cooking quality (Feillet & Dexter, 1996). An important aspect of durum wheat is that its endosperm has a relatively high carotenoid content, which gives the yellow color to the grain and this color is transferred to the products such as spaghetti (Matsuo, 1988).

According to Ames et al. (1999), pasta is important from a nutritional point of view, and is expected that consumption of durum worldwide will continue to increase.

To evaluate durum wheat quality, Cereal Chemists use three important characteristics: 1) kernel intrinsic characteristics, 2) milling and semolina characteristics and facility of processing, and 3) quality of the final product (Matsuo, 1988). Many variables are involved in pasta quality, which have been defined previously. Some authors find protein content and gluten quality the most important variables determining pasta cooking quality (D'Egidio et al., 1990; Novaro et al., 1990; Fois et al., 2011). Gluten composition is the main factor affecting durum dough mixing strength and processing quality. From the protein fractions, gliadin gives dough extensibility, whereas, glutenin gives dough elasticity (Edwards et al., 2003).

In 2005, Mexico had a wheat production of 2.4 MT, and the main producer states were, Sonora (35%), Guanajuato (17.5%), Baja California Norte (11.5%), Sinaloa (9.2%), Michoacán (6.4%) and Jalisco (4.4%) (SAGARPA, 2005). The main wheat cultivars are for bread and pasta preparation. Durum wheat is grown mainly in the state of Sonora, and during year 2004 its production was 301,350 MT (Cosemex, 2003). The Mexican durum wheat production includes cultivars with good quality characteristics.

The pasta industry in Mexico has had great growth, because pasta represents an available, nutritious food

alternative. Nowadays, most of the Mexican pasta production is made with durum wheat semolina and its quality is acceptable.

Sonora is a semiarid state, with a low average annual precipitation (less than 100 mm). However, due to the large extensional territory among its regions, there are large differences in environmental conditions (temperature and relative humidity) and soil types. The northern and central regions are the driest zones, and durum wheat is irrigated with water coming from wells. On the other hand, the southern region has a higher average annual precipitation and durum wheat is irrigated with water coming from dams. This environment and the genotypes of the different durum wheat cultivars from Sonora State and their interaction could affect the final quality of the grain, semolina and pasta.

Rheology of dough wheat flours has been an interesting topic for several decades. Comprehension of the behavior of dough with respect to flow and deformation is an aspect of great relevance in the preparation of products, such as bread and pasta. Pasta quality can be predetermined by rheological evaluations. Peressini et al. (1999) and Edwards et al. (2001) established that viscoelastic properties of durum semolina dough was related to dough mixing strength, baking characteristics and pasta quality. Traditionally, dough rheological properties have been determined using instruments such as the Farinograph, Mixograph, Extensograph or Alveograph. These apparatus give a number of physical indicators of dough strength. However, they do not give information about fundamental linear viscoelastic properties (LVP). Studying the rheological properties of gluten and dough, may help to understand the macromolecular structures in gluten, which is responsible for its physical properties (Rao et al., 2001).

One of the most frequently used methods to study dough viscoelastic properties is the dynamic method, which has been adapted from techniques utilized in polymer research. As a result of the dynamic test, well defined rheological parameters are obtained that help to characterize complex materials such as semolina dough made from durum wheat.

The semolina quality obtained from Mexican DURUM wheat cultivars has not been evaluated with respect to their viscoelastic properties. We consider it critical to characterize the viscoelastic properties of those semolinas. The objective of this research is to evaluate

the viscoelastic properties of semolina dough made from Mexican durum wheat cultivars.

Materials and Method

Wheat Samples

Thirteen and eleven grain samples (15 kg each) of 6 durum wheat cultivars were obtained during winter-spring 2001-2002 and 2002-2003, respectively, from locations within the main durum producing states of México: Sonora, Sinaloa and Baja California Norte. Durum wheat cultivars were: Aconchi, Atil, Nácori, Altar, Rafi and Sofia. Each sample was grown under different environmental conditions. Each durum wheat sample was cleaned using a commercial cleaner (Clipper, Model M2BC). Furthermore, commercial semolina (North Dakota Mill, Grand Forks, ND USA) was used to compare the viscoelastic properties of Mexican semolina.

Semolina Preparation

Preparation of semolina was carried out in the Laboratory of Dr. Frank Manthey at North Dakota University, Fargo ND, USA. The procedure to obtain semolina was as follows (Manthey & Schorno, 2002): Durum wheat samples (4 kg each) were cleaned using a Carter-Day cleaner (Carter-Day, Simon-Carter Co. Minneapolis MN), configured with a Number 25 riddle and Number 8 and Number 2 sieves. The wheat grain was conditioned to 12.5% moisture 72 h before milling. Then 24 h before milling, the wheat grain was conditioned from 12.5 to 14.5% moisture, and finally, it was conditioned from 14.5 to 17.5% moisture, 45 min before milling. The conditioned wheat grain was milled into semolina using a Bühler experimental mill fitted with two Miag laboratory-scale purifiers (Bühler-Miag, Minneapolis, MN).

Chemical and Physical Evaluations

Contents of protein (%N $\times$ 5.7), ash and moisture in the semolinas were determined by methods 46-13, 08-03 and 44-40, respectively, (AACC, 2000). Wet gluten was measured using method 38-11 (AACC, 2000).

Semolina Dough Preparation

Dough was prepared using 50 g each semolina, and adding distilled water. The water amount used was to obtain a dough with 40% moisture content. Semolina and water were mixed for three minutes in a mixer with a bowl 300 g capacity (National MFG, Lincoln Nebraska, USA). The dough was placed in a plastic

bag during 30 min at room temperature (25 °C). Then the semolina dough was removed from the plastic bag and rested 30 min in a proofing chamber (National MFG, Lincoln, Nebraska) at 30°C and 95% relative humidity.

Viscoelasticity Evaluation

Oscillatory measurements were conducted at 0.1% strain within the linear viscoelastic regime, over a frequency range of 0.5 to 100 rad/s. Frequency sweep experiments were conducted in a rheometer (Rheometrics Scientific, model RSF III, Piscataway, NJ). The rheometer was equipped with 25-mm diameter parallel plates that were maintained at 25°C. A dough sample 2.6 g was round by hand and placed between the plates of the rheometer. The sample was gently flattened to fit the plate geometry using a Teflon-coated spatula. The upper plate was lowered to a fixed gap between plates of 2.5 mm. The exposed edges of dough were trimmed, and to avoid drying, petroleum jelly was injected around the plates. The dynamic rheological parameters evaluated were storage modulus (G'), loss modulus (G''), and loss tangent ($\tan \delta = G''/G'$). These parameters were obtained using the software analysis program of the rheometer.

Experimental Design and Statistic Analysis

One way experimental design was used: wheat cultivars. This design was applied for each crop year. Analyses of variance were performed on the data obtained from the different determinations. Difference among specific treatments was tested with the Tukey's test. Statistical analyses were performed using Statistical Analytical System Software (SAS, 2000, Raleigh, NC).

Results and Discussion

Chemical and Physical Evaluations

Tables 1 and 2 presented the proximal composition and wet gluten content of semolina from the different durum wheat cultivars harvested in crop years 2001-2002 and 2002-2003, respectively. The Nacori and Rafi cultivars had the higher protein content from crop year 2001-2002, and crop year 2002-2003, respectively. The protein content of the wheat cultivar was similar, but slightly higher for crop year 2001-2002 than crop year 2002-2003. These changes could be attributed to possible difference in environmental temperature (Fois et al., 2011). Protein content is an important factor,

and in the USA, pasta processors often specify that semolina should have a minimum protein content of 12.5%. However, in some crop years, the wheat protein content was low and they accepted durum with 12% protein content. Semolina made of Mexican durum wheat cultivars gave a slightly lower protein content, which could affect their dough viscoelastic properties.

The ash content was similar for all durum wheat cultivars, but slightly higher for crop year 2002-2003 than crop 2001-2002. These ash contents were in the range of the optimum values for a good quality semolina to elaborate pasta (Pomeranz, 1988).

TABLE 1 SEMOLINA PROXIMAL COMPOSITION AND WET GLUTEN CONTENT FROM MEXICAN DURUM WHEAT CULTIVARS: CROP YEAR 2001-2002

Cultivar	Moisture content (%)	Protein Content ^{1,2} (%)	Ash content ¹ (%)	WG content ³ (%)
Aconchi	14.39± 0.00 ^{4a5}	11.02± 0.04ab	0.62± 0.03a	29.69± 0.20a
Altar	14.47± 0.15a	10.96± 0.38b	0.64± 0.06a	30.06 ± 1.46a
Nacori	14.34± 0.11a	11.86± 0.69a	0.60± 0.02a	30.56± 2.13a
Rafi	14.41± 0.12a	11.03± 0.47b	0.60± 0.05a	30.00± 0.50a

¹Dry basis

²Conversion Factor Nx5.7

³WG = Wet gluten

⁴Standar Desviation

⁵Within a column, means with the same letter are not statistically different at p= 0.05 (p>0.05)

TABLE 2 SEMOLINA PROXIMAL COMPOSITION AND WET GLUTEN CONTENT FROM MEXICAN DURUM WHEAT CULTIVARS: CROP YEAR 2002-2003

Cultivar	Moisture content (%)	Protein Content ^{1,2} (%)	Ash content ¹ (%)	WG content ³ (%)
Altar	13.51± 0.35 ^{4a5}	10.80± 0.49ab	0.67± 0.04ceg	29.55± 2.15ab
Atil	13.21± 0.13a	10.47± 0.05ab	0.64± 0.01bef	30.27 ± 0.63ab
Rafi	13.42± 0.65a	11.03± 0.07a	0.71± 0.01a	30.54± 1.03a
Sofia	13.08± 0.04a	10.31± 0.09b	0.62± 0.01dfg	26.93± 0.16b

¹Dry basis

²Conversion Factor Nx5.7

³WG = Wet gluten

⁴Standar Desviation

⁵Within a column, means with the same letter are not statistically different at p= 0.05 (p>0.05)

Semolina wet gluten was similar for crop years 2001-2002 (range: 29.69-30.56%) and 2002-2003 (range: 29.66-30.54%), and Nacori and Rafi cultivars had the higher values for each year, and this coincided with the high protein content observed. Gluten characteristics gave

an indication of functional characteristics (Pomeranz, 1988) and cooking quality of pasta (Fois et al., 2011). On the other hand, the gluten quality had an important role in pasta textural characteristics, due to that semolina required strong gluten (Fois et al., 2011). If protein content is low, the pasta will tend to disintegrate during cooking.

Semolina Viscoelastic Characteristics

Storage modulus (G'), loss modulus (G'') and loss tangent ($\tan \delta = G''/G'$) for semolina dough obtained from Mexican durum wheat cultivars harvested on crop years 2001-2002 and 2002-2003 are presented on FIGS. 1 (A and B), 2(A and B) and 3 (A and B), respectively. In those figures, the viscoelastic characteristics of the commercial semolina dough are included.

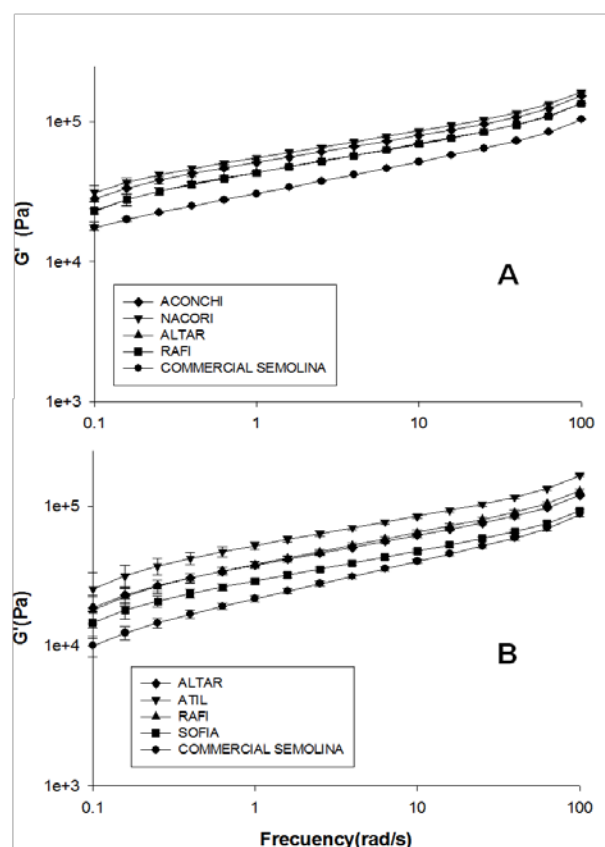


FIG. 1 STORAGE MODULUS (G') FOR SEMOLINA DOUGH OBTAINED FROM MEXICAN DURUM WHEAT CULTIVARS HARVESTED ON CROP YEARS 2001-2002 (A) AND 2002-2003 (B). (BARS INDICATE STANDARD DEVIATION).

FIG. 1 A presents the storage modulus (G') of semolina dough made from durum wheat harvested on crop year 2001-2002. For all cultivars and commercial semolina, G' increase with the frequency range from 0.1 to 100 rad/s. Regarding to the magnitude of G' , statistically ($p > 0.05$) there are no differences among cultivars. However, G' values of

semolina dough from Mexican cultivars are higher than commercial semolina dough. In FIG. 1B it is observed G' values for semolina dough of crop year 2002-2003. The G' trends are similar to those from semolina dough from Mexican wheat cultivars of crop year 2001-2002.

Figures 2A and 2B present the loss modulus (G'') from semolina dough made with wheat cultivars of crops years 2001-2002 and 2002-2003, respectively. As with G' , G'' increased with frequency for both crop years. In crop year 2001-2002, there were no significant differences in G'' values among semolina dough from the different durum cultivars, whereas in crop year 2002-2003, G'' was affected by the cultivar. In FIG. 2B it is observed that Atil cultivar has the curve with the highest G'' values, while Sofia and the commercial semolina dough gave the lowest curves.

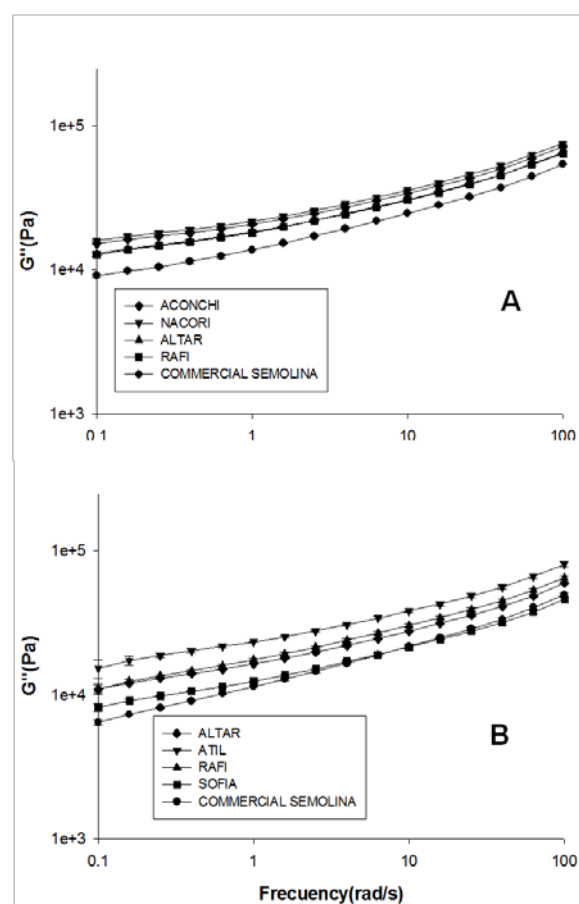


FIG. 2 LOSS MODULUS (G'') FOR SEMOLINA DOUGH OBTAINED FROM MEXICAN DURUM WHEAT CULTIVARS HARVESTED ON CROP YEARS 2001-2002 (A) AND 2002-2003 (B). (BARS INDICATE STANDARD DEVIATION).

$\tan \delta$ (G''/G') from both crop years is presented in FIGS. 3A and 3B. For crop year 2001-2002, for all the semolina doughs, $\tan \delta$ did not change in the frequency ranging from 1 to 10 rad/s (FIG. 3A). According to the analysis of variance, wheat cultivars

affected significantly this parameter ($p < 0.05$). With respect to the $\tan \delta$ value, all the semolina doughs had higher elastic characteristics than viscous characteristics ($\tan \delta < 0.5$). Commercial semolina dough had the highest value of $\tan \delta$ (> 0.5), which indicated that the viscous characteristic predominated over the elastic characteristic. The cultivar Altar (crop year 2002-2003) had the lowest $\tan \delta$ value from all the semolina dough wheat cultivars, which indicated semolina dough with the highest elastic characteristic. This behavior can be attributed at the highest wet gluten content and protein quality observed by microsedimentation, coincided with others authors (Samaan et al., 2006).

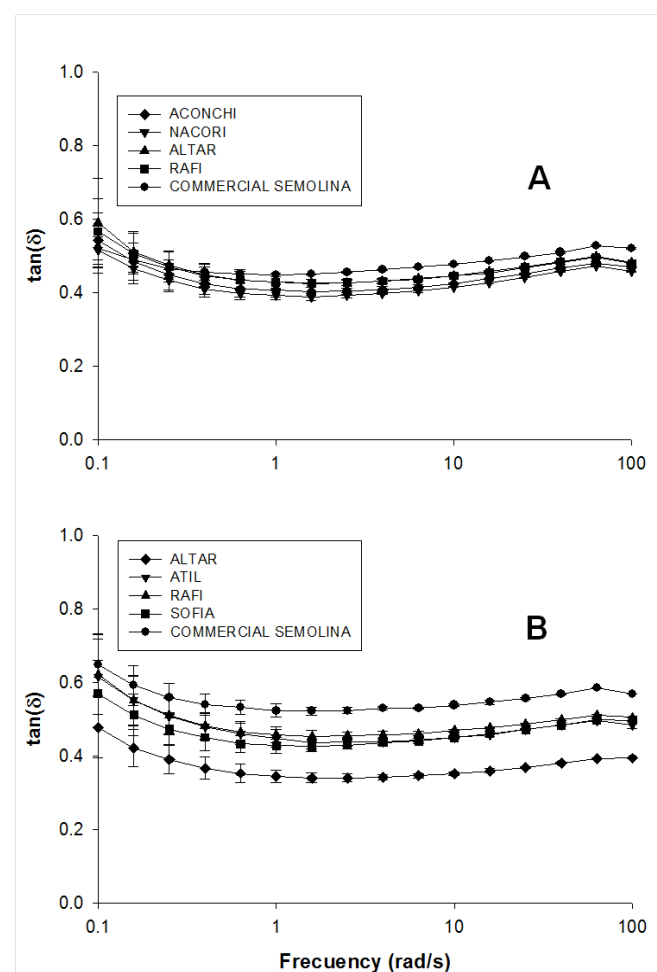


FIG. 3 ANGLE δ TANGENT ($\tan \delta = G''/G'$) FOR SEMOLINA DOUGH OBTAINED FROM MEXICAN DURUM WHEAT CULTIVARS HARVESTED ON CROP YEARS 2001-2002 (A) ADN 2002-2003 (B). (BARS INDICATE STANDARD DEVIATION).

Conclusions

The dynamic method in the frequency sweep mode, was appropriate for the study of the viscoelastic behavior of the dough of semolina made from durum wheat cultivars grown in Mexico. Semolina dough

viscoelastic properties were strongly affected by the variety of wheat and not by environmental conditions in both crop years. The storage modulus G' and loss modulus G'' were highest in semolina made with Mexican cultivars among those viscoelastic parameters of the commercial semolina used. The $\tan \delta$ was the principal viscoelastic parameter affected by wheat cultivar. The $\tan \delta$ of semolina dough of Mexican cultivars was less than 0.5, which indicates that dough had more elastic than viscous contribution. According with this parameter ($\tan \delta$), Nacori cultivars had the best viscoelastic characteristics in both crop years. Nacori cultivar had the highest protein and wet gluten content.

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